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UTILITY PATENT APPLICATION TRANSMITTAL

(Only for new nonprovisional applications under 37 CFR 1.53(b))

Attorney Docket No.	2272-010
First Inventor	Ismail Lakkis
Title	Method and Apparatus...Communications
Express Mail Label No.	EL697039167US

APPLICATION ELEMENTS

See MPEP chapter 600 concerning utility patent application contents.

ADDRESS TO: Assistant Commissioner for Patents
Box Patent Application
Washington, DC 20231

1. [x] Fee Transmittal Form (e.g., PTO/SB/17)
   (Submit an original and a duplicate for fee processing)

2. [x] Applicant claims small entity status.
   See 37 CFR 1.27.

3. [x] Specification [Total Pages 40]
   (preferred arrangement set forth below)
   - Descriptive title of the invention
   - Cross Reference to Related Applications
   - Statement Regarding Fed sponsored R & D
   - Reference to sequence listing, a table, or a computer program listing appendix
   - Background of the Invention
   - Brief Summary of the Invention
   - Brief Description of the Drawings *(if filed)*
   - Detailed Description
   - Claim(s)
   - Abstract of the Disclosure

4. [x] Drawing(s) *(35 U.S.C. 113)* [Total Sheets 8]

5. Oath or Declaration [Total Pages 2]
   a. [X] Newly executed (original or copy)
   b. [ ] Copy from a prior application (37 CFR 1.63 (d))
      (for continuation/divisional with Box 17 completed)
      i. [ ] **DELETION OF INVENTOR(S)**
      Signed statement attached deleting inventor(s) named in the prior application, see 37 CFR 1.63(d)(2) and 1.33(b).

6. [ ] Application Data Sheet. See 37 CFR 1.76

7. [ ] CD-ROM or CD-R in duplicate, large table or Computer Program (*Appendix*)

8. Nucleotide and/or Amino Acid Sequence Submission (*if applicable, all necessary*)
   a. [ ] Computer Readable Form (CRF)
   b. Specification Sequence Listing on:
      i. ☐ CD-ROM or CD-R (2 copies); or
      ii. ☐ paper
   c. [ ] Statements verifying identity of above copies

PTO U.S. PTO JC564 09/670054 09/25/00

ACCOMPANYING APPLICATION PARTS

9. [ ] Assignment Papers (cover sheet & document(s))

10. [ ] 37 CFR 3.73(b) Statement *(when there is an assignee)* [ ] Power of Attorney

11. [ ] English Translation Document *(if applicable)*

12. [x] Information Disclosure Statement (IDS)/PTO-1449 [X] Copies of IDS Citations

13. [ ] Preliminary Amendment

14. [x] Return Receipt Postcard (MPEP 503) *(Should be specifically itemized)*

15. [ ] Certified Copy of Priority Document(s) *(if foreign priority is claimed)*

16. [x] Other: Check for $399.00 filing fee.

17. If a CONTINUING APPLICATION, *check appropriate box, and supply the requisite information below and in a preliminary amendment, or in an Application Data Sheet under 37 CFR 1.76:*

[ ] Continuation   [ ] Divisional   [ ] Continuation-in-part (CIP)   of prior application No.:_____/_____

Prior application information: Examiner _____   Group I Art Unit: _____

For CONTINUATION OR DIVISIONAL APPS only: The entire disclosure of the prior application, from which an oath or declaration is supplied under Box 5b, is considered a part of the disclosure of the accompanying continuation or divisional application and is hereby incorporated by reference. The incorporation <u>can only</u> be relied upon when a portion has been inadvertently omitted from the submitted application parts.

18. CORRESPONDENCE ADDRESS

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Signature	*Lowell W. Gresham*	Date	25 Sept. 2000

In the application of: Ismail Adnan Lakkis

Serial No.:

Filed: Herewith

For: *METHOD AND APPARATUS FOR WIRELESS COMMUNICATIONS*

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Indep	3	Minus	3	= 0	X 39	$ -0-	x 78	$ -0-
First Presentation of Mult. Dep. Claims					X 130	$ -0-	x 260	$ -0-
					Total	$ 399	or Total	$ -0-

_X_   A check in the amount of $399.00 is enclosed

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DATED: *25 September 2000*

Respectfully Submitted.

Lowell W. Gresham
Attorney for Applicant(s)
Reg. No. 31,165

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant: Ismail Adnan Lakkis)
)
Serial No.:)
)
Filed: HEREWITH)
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For: METHOD AND APPARATUS FOR WIRELESS COMMUNICATIONS)
)

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I hereby certify that this correspondence, consisting of this Certificate of Mailing by

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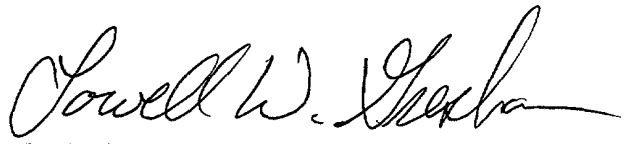**25 September 2000**
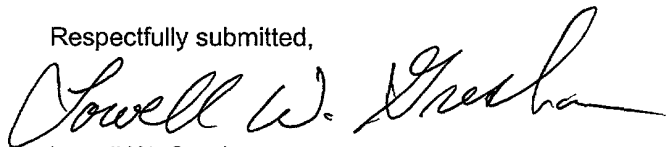Date

25 September 2000

Signature

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Applicants or Patentees: Ismail A. Lakkis
Serial or Patent No.:
Filed or Issued: Herewith
For: *METHOD AND APPARATUS FOR WIRELESS COMMUNICATIONS*

Attorney's
Docket No.: 2272-010

VERIFIED STATEMENT (DECLARATION) CLAIMING SMALL ENTITY STATUS (37 CFR 1.9(f) and 1.27(b))-INDEPENDENT INVENTOR

As a below-named inventor, I hereby declare that I qualify as an independent inventor as defined in 37 CFR 1.9(c) for purposes of paying reduced fees under section 41(a) and (b) of Title 35, United States Code, to the Patent and Trademark Office with regard to the invention entitled, *METHOD AND APPARATUS FOR WIRELESS COMMUNICATIONS*

described in

  __X__   the specification filed herewith
  _____   application serial no. _____, filed _____
  _____   patent no. _____, issued _____

I have not assigned, granted, conveyed or licensed and am under no obligation under contract or law to assign, grant, convey or license, any rights in the invention to any person who could not be classified as an independent inventor under 37 CFR 1.9(c) if that person had made the invention, or to any concern which would not qualify as a small business concern under 37 CFR 1.9(d) or a nonprofit organization under 37 CFR 1.9(e).

Each person, concern or organization to which I have assigned, granted, conveyed, or licensed or am under an obligation under contract or law to assign, grant, convey, or license any rights in the invention is listed below:

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  _____   persons, concerns or organizations listed below*

    *NOTE: Separate verified statements are required from each named person, concern or organization having rights to the invention averring to their status as small entities. (37 CFR 1.27)

FULL NAME _____

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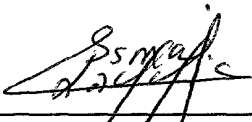
I acknowledge the duty to file, in this application or patent, notification of any change in status resulting in loss of entitlement to small entity status prior to paying, or at the time of paying, the earliest of the issue fee or any maintenance fee due after the date on which status as a small entity is no longer appropriate. (37 CFR 1.28(b)).

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application, any patent issuing thereon, or any patent to which this verified statement is directed.

SOLE or FIRST INVENTOR:

_____
Ismail A. Lakkis

Sept ,20, 2000
Date

METHOD AND APPARATUS FOR WIRELESS COMMUNICATIONS

TECHNICAL FIELD OF THE INVENTION

The present invention relates generally to the field of
5   wireless communications. More specifically, the present
invention relates to a spread-spectrum-based wireless
communication system and method that efficiently utilize
spectrum in the presence of multipath.

BACKGROUND OF THE INVENTION

The electromagnetic spectrum used to convey radio
communications is a precious commodity. Communication
systems seek to use this spectrum as efficiently as possible
to maximize the capacity or quantity of information which can
15   be conveyed using the spectrum.

Various multiple access techniques have been developed to
transfer information among a number of users, all while
efficiently using spectrum. Time division multiple access
(TDMA) techniques assign different users to different time
20   slots. Capacity is hard limited by the number of time slots
available. To prevent intolerable interference, the portion
of the spectrum used in one radio coverage area or cell has
conventionally been unusable in adjacent cells. Thus, only a
fraction, typically less than one-third, of the entire
25   spectrum available for conveying communications has been
conventionally usable in any one location. In other words,
conventional TDMA systems employ a frequency reuse pattern of
at least three, indicating an inefficient use of spectrum.

Conventional direct sequence spread spectrum (DSSS) code
30   division multiple access (CDMA) techniques theoretically use
the spectrum more efficiently than TDMA techniques. However,
in practice conventional DSSS-CDMA techniques typically fail

to provide results significantly better than TDMA. DSSS-CDMA
techniques assign different users to different codes. The
different codes have conventionally been selected because of
orthogonality or low cross correlation properties with the
5   codes of other users. These properties minimize
interference. All communications are broadcast using the
same spectrum, so the frequency reuse pattern equals one.
While the commonly used spectrum conveys a composite of
communications for all users, each individual user's
10   communications are extracted from the composite by
correlating a received signal against the individual user's
assigned code.

Capacity in conventional DSSS-CDMA systems is
interference limited. In other words, more and more codes
15   can be assigned so that the given amount of spectrum can
service more and more users until interference reaches a
level where only a minimally acceptable quality of service
results. In practice, most conventional DSSS-CDMA systems
can assign far fewer codes than appear theoretically possible
20   due to a near-far effect and multipath. The near-far effect
results when signals from different users are received with
greatly differing field strengths, but this detrimental
effect may be ameliorated somewhat by power control.

Multipath results when the transmitted signal takes
25   multiple paths to the receiver due to being reflected from
and deflected around obstacles in the environment. As the
signal propagates over the multiple paths, different
propagation delays are experienced. Thus, a signal
transmitted at a precise instant in time is received spread
30   over an interval, causing the signal to interfere with
itself. In conventional DSSS-CDMA communication systems,

multipath tends to destroy the orthogonality of spreading codes, resulting in dramatically increased interference.

SUMMARY OF THE INVENTION

It is an advantage of the present invention that an improved method and apparatus for wireless communications are provided.

Another advantage of the present invention is that it combines TDMA and spread spectrum techniques so that wireless communications capacity is increased over the capacities achievable through conventional TDMA and/or CDMA systems using an equivalent amount of spectrum.

Another advantage of the present invention is that robust, simple, and inexpensive processing techniques are usable, making the present invention suitable for hubs, subscriber units, mobile stations, fixed stations, portable stations, and the like.

Another advantage is that the present invention may be adapted to and used in conjunction with a variety of modulation and multiple access techniques, such as frequency division multiple access (FDMA) and orthogonal frequency division multiplexing (OFDM).

Another advantage of the present invention is that a composite RF communication signal includes signal components obtained by modulating diverse branches of a single user's data stream using cyclic variants of a common spreading code.

Another advantage is that the present invention is configured to tolerate self-interference and is better able to tolerate multipath than conventional DSSS-CDMA communication systems.

These and other advantages are realized in one form by an improved spread-spectrum-based communication system which

efficiently utilizes spectrum in the presence of multipath. The communication system includes a demultiplexer for dividing a stream of data-conveying symbols into a plurality of unspread substreams. A spreading section couples to the demultiplexer and is configured to generate spread substreams from the plurality of unspread substreams. The spreading section is configured so that the spread substreams correspond to respective ones of the unspread substreams modulated by cyclic variations of a common spreading code. A combining section couples to the spreading section and is configured to form a composite signal in response to the spread substreams. A transmission section couples to the combining section and is configured to wirelessly transmit a communication signal formed from the composite signal. A receiving section receives the communication signal, and a despreading section couples to the receiving section. The despreading section generates a baseband signal in response to the communication signal.

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete understanding of the present invention may be derived by referring to the detailed description and claims when considered in connection with the Figures, wherein like reference numbers refer to similar items throughout the Figures, and:

FIG. 1 shows a layout diagram of an exemplary environment in which the present invention may be practiced;

FIG. 2 shows a timing diagram which depicts a temporal format of a TDMA communication signal;

FIG. 3 shows a block diagram of a transmitter and a receiver configured in accordance with the teaching of the present invention;

FIG. 4 shows a timing diagram depicting how a cyclic spreading code is applied to blocks of unspread data streams in accordance with first, second and third embodiments of a DSSS modulation section in the transmitter of the present invention;

FIG. 5 shows a block diagram of the first embodiment of the DSSS modulation section;

FIG. 6 shows a block diagram of the second embodiment of the DSSS modulation section;

FIG. 7 shows a block diagram of the third embodiment of the DSSS modulation section;

FIG. 8 shows a first embodiment of a CDM to TDM converter section in the receiver of the present invention;

FIG. 9 shows an exemplary spectral analysis of a suitable spreading code usable in connection with the present invention, the spectral analysis showing a substantially flat response;

FIG. 10 shows an exemplary timing diagram of various individual signal components present in a composite signal output from a matched filter portion of a mismatched filter in the CDM to TDM converter;

FIG. 11 shows a timing diagram depicting how a cyclic spreading code is applied to blocks of unspread data streams in fourth and fifth embodiments of the DSSS modulation section;

FIG. 12 shows a block diagram of the fourth and fifth embodiments of the DSSS modulation section;

FIG. 13 shows a second embodiment of the CDM to TDM converter for use with the fourth embodiment of the DSSS modulation section; and

FIG. 14 shows a third embodiment of the CDM to TDM converter for use with the fifth embodiment of the DSSS modulation section.

5   **DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS**

FIG. 1 shows a layout diagram of an exemplary environment in which a communication system 20 configured in accordance with the teaching of the present invention may be practiced. Communication system 20 includes any number of transmitters

10 (TX's) 22 (three shown) and any number of receivers (RX's) 24 (five shown). Transmitters 22 wirelessly broadcast messages through RF time domain multiple access (TDMA) communication signals 26 which are receivable by receivers 24 located within radio coverage areas 28 for the transmitters 22.

15 Radio coverage areas 28 may also be called cells or sectors. As illustrated in FIG. 1, various ones of radio coverage areas 28 may be adjacent to one another and even overlap to some extent. In the preferred embodiment, a common spectrum is used in all radio coverage areas 28 so that communication

20 system 20 has a frequency reuse pattern substantially equal to one.

For the sake of clarity, FIG. 1 depicts only a forward link in which radio equipment is viewed as being only a transmitter 22 or a receiver 24. However, those skilled in

25 the art will appreciate that a reverse link may also be implemented and that each item of equipment may have both a transmitter and receiver. The reverse link may use the same or a different spectrum from the forward link. If a forward link conforms to the teaching of the present invention, then

30 the reverse link may or may not conform, and vice versa.

FIG. 2 shows a timing diagram which depicts an exemplary temporal format for TDMA communication signal 26. FIG. 2

specifically depicts two frames 30, each of which is temporally subdivided into any number of timeslots 32. Different timeslots 32 are preferably assigned to different receivers 24 (FIG. 1) in a manner well understood in the art

5   so that different recipients are distinguished from one another by being assigned to the different time slots 32. In the preferred embodiments, TDMA communication signal 26 consumes the entire common spectrum for each time slot 32. Nothing requires a time slot 32 to be assigned to receivers

10 24 for an indefinite period or to be of the same duration as other time slots 32.

Each time slot 32 of TDMA communication signal 26 is subdivided into successive blocks 34 of symbols 36. FIG. 2 labels blocks 34 with the identifiers B_k, for k = 0 to K-1,

15 where K is an integer number. Any number of blocks 34 may be included in each timeslot 32. Each block B_k includes M symbols 36, labeled as $a_{k,m}$ for m = 0 to M-1, where M is an integer number. FIG. 2 illustrates each of symbols 36 within a block 34 as being concurrently present throughout the

20 entire duration of a block period because certain preferred embodiments discussed below configure symbols 36 to remain present for block periods.

FIG. 2 further illustrates that the M symbols 36 of each block 34 are spread using an N-chip spreading code 38,

25 labeled as C_n, for n = 0 to N-1, where N is an integer number. As discussed in more detail below, each symbol 36 is independently spread using cyclic variations of the same common code 38. The number M of symbols 36 in a block may equal the number N of chips in a spreading code, in which

30 case the spreading factor equals one. However, performance improvements result when N is greater than M.

FIG. 3 shows a block diagram of a single transmitter 22 and a single receiver 24 configured in accordance with the teaching of the present invention. Those skilled in the art will appreciate that all transmitters 22 and receivers 24 may be configured similarly. In addition, any number of receivers 24 may, at any given instant, receive TDMA communication signal 26 from a given transmitter 22 and, in fact, may receive TDMA communication signals 26 from more than one transmitter 22.

Transmitter 22 includes a TDMA modulation section 40 which generates a TDMA-configured stream 42 of data conveying symbols 36. Stream 42 feeds a direct sequence spread spectrum (DSSS) modulation section 44, which generates a composite signal 46. Composite signal 46 feeds a transmission section 48, which forms TDMA communication signal 26 from composite signal 46 and wirelessly broadcasts TDMA communication signal 26 for reception by receivers 24 located within radio coverage area 28 (FIG. 1) of transmitter 22.

Within TDMA modulation section 40 any number of data sources 50 supply digital data to a multiplexer (MUX) 52. The digital data from data sources 50 may be intended for any number of receivers 24. Multiplexer 52 groups the digital data so that data intended for different receivers 24 are serially fed to a cyclic redundancy check (CRC) section 54 in accordance with the assignment of timeslots 32 (FIG. 2) to receivers 24. CRC section 54 provides forward error correction in a manner well understood by those skilled in the art.

From CRC section 54, the input data stream may be fed through a scrambler 56 which randomizes the data to an encode and interleave section 58. Section 58 may apply another type

of error correction, such as convolutional or turbo encoding, to the input stream, and interleave the data. CRC section 54 and section 58 may utilize a form of block encoding. The block size or boundaries of such encoding need have no relationship to blocks 34 (FIG. 1), discussed above.

However, the output of section 58 feeds an optional peak-to-average (P/A) block encoding section 60. P/A block encoding section 60 applies a type of encoding which primarily reduces the peak-to-average power ratio in composite signal 46 and thereby lessens the demands placed on a power amplifier included in transmission section 48 to faithfully reproduce communication signal 26 with a minimum amount of distortion. This type of encoding may, but is not required to, provide additional coding gain. In the preferred embodiments, when P/A block encoding section 60 is included, it applies block encoding so that encoded blocks coincide with successive blocks of symbols 36 (FIG. 2), discussed above. In other words, the data are encoded so that P/A encoded blocks begin with symbol 36 $a_{k,0}$ (FIG. 2) and end with symbol 36 $a_{k,m}$ (FIG. 2).

P/A block encoding section 60 feeds a constellation encoding section 62 which converts the data into complex symbols in accordance with a predetermined phase constellation. As an example, each four-bit group of data output from P/A block encoding section 60 may be mapped by section 62 into a single complex symbol having in-phase and quadrature components in accordance with a 16-QAM phase constellation. However, those skilled in the art will appreciate that the present invention may be used with any type or size of phase constellation.

The stream of complex symbols output from constellation encode section 62 passes through a synchronization

multiplexer (SYNC MUX) 64, where a preamble 66 is inserted into the stream at appropriate intervals. Preamble 66 is a known code which helps receivers 24 obtain synchronization and determine the timing of frames 30 and time slots 32 (FIG. 2). The resulting TDMA-configured complex stream 42 serves as the output from TDMA modulation section 40 and feeds DSSS modulation section 44.

Within DSSS modulation section 44, a demultiplexer (DEMUX) 68 divides TDMA-configured stream 42 of complex symbols 36 into blocks 34 (FIG. 2) of symbols 36. As a result, M unspread complex symbol substreams 70 are provided by demultiplexer 68 so that each unspread substream 70 contributes a single complex symbol 36 during each block 34, and each block 34 has a block period T*M, where T is the symbol period of TDMA-configured stream 42.

Unspread substreams 70 feed a spreading section 72. Within spreading section 72, cyclic variations of common spreading code 38 (FIG. 2) are applied to the M unspread substreams 70 to form M spread substreams 74 of "chips." The chip period in each spread substream 74 is T*M/N. The M spread substreams 74 may be passed through an optional peak-to-average (P/A) reduction section 76 which adjusts phase angles of the complex chips conveyed in the spread substreams 74 in a manner understood by those skilled in the art to reduce peak-to-average power ratio and lessen demands placed on a power amplifier. Following P/A reduction section 76, a combining section 78 combines spread substreams 74 to form composite signal 46. Various embodiments of DSSS modulation section 44 are discussed in more detail below.

Transmission section 48 includes any number of components and functions well known to those skilled in the art. For example, scrambling section 56 and/or synchronization

multiplexer 64, discussed above, may be included in transmission section 48 rather than in TDMA modulation section 40. A pulse shaping section (not shown) is desirably included in transmission section 48 to spread the energy from

5   each chip over a number of chip intervals using a suitable filter which minimizes inter-symbol or inter-chip interference so that spectral constraints may be observed. Transmission section 48 may also include digital-to-analog conversion, quadrature modulation, up-conversion, and power

10 amplification functions, all implemented in conventional fashion. Power control may be implemented in transmission section 48 at the power amplifier to ameliorate a potential near-far problem, which should be much less pronounced in communication system 20 (FIG. 1) than in traditional CDMA

15 communication systems. After pulse shaping, analog conversion, up-conversion, and amplification, TDMA communication signal 26 is formed from composite signal 46 and wirelessly broadcast from transmission section 48.

Receiver 24 receives TDMA communication signal 26.

20 Within receiver 24, communication signal 26 is processed through a receiving section 80 and passed to a code division multiplex (CDM) to time division multiplex (TDM) converter 82. CDM to TDM converter 82 produces a baseband signal 84 which is further demodulated in a TDM demodulation section

25 86, with individual users receiving their respective data streams 88. Of course, nothing requires a receiver 24 to serve multiple users and TDM demodulation section 86 may simply provide a data stream intended for a single user.

Receiving section 80 includes any number of components

30 and functions well known to those skilled in the art. For example, amplifying, filtering, and down-conversion may be performed to form an intermediate frequency (IF) signal. The

IF signal may be converted from an analog form into a digital form, and automatic gain control (AGC) may be provided. In the preferred embodiments, the digitized form of the down-converted communication signal 26 passes to CDM to TDM converter 82.

Generally, CDM to TDM converter 82 performs despreading and optionally performs equalization on the communication signal. Various embodiments of CDM to TDM converter 82 are discussed in more detail below.

TDM demodulation section 86 includes any number of components and functions well known to those skilled in the art. For example, channel estimation and synchronization may be performed in TDM demodulation section 82. A rake receiver and/or equalizer may be included. De-interleaving, error correction decoding, and descrambling are desirably performed, and preambles and other control data are evaluated to detect time slots assigned to the receiver 24. These and other components and functions conventionally used in digital demodulators may be included in TDM demodulation section 86.

FIG. 4 shows a timing diagram depicting how common spreading code 38 (FIG. 2) is applied to blocks 34 (FIG. 2) of unspread data substreams 70 (FIG. 3) in accordance with first, second and third embodiments of DSSS modulation section 44 (FIG. 3) in transmitter 22 (FIG. 3). FIG. 4 is presented in tabular form, with rows representing the application of the chips of common spreading code 38 to symbols 36 (FIG. 2). Columns in FIG. 4 depict successive blocks 34. As indicated by a shaded region in FIG. 4, spreading code 38 is applied to unspread substreams 70 so that composite signal 46 is influenced, at least for a portion of the time, by symbols 36 from two different blocks 34. In particular, in the specific embodiment depicted by

FIG. 4, for only a single chip of each block period is composite signal 46 influenced by symbols 36 from a common block 34 of symbols. The manner of application of common spreading code 38 (FIG. 2) to blocks 34 (FIG. 2) of unspread data substreams 70 depicted in FIG. 4 may be contrasted with an alternate embodiment, discussed below in connection with FIG. 11.

FIG. 5 shows a block diagram of the first embodiment of DSSS modulation section 44. Demultiplexer 68 is omitted from FIG. 5 for convenience. The unspread substream 70 conveying symbols $a_{k,0}$ experiences no delay before being fed to a first input of a multiplier 90. However, the unspread substreams 70 conveying symbols $a_{k,1}$ through $a_{k,M-1}$ are respectively delayed in delay elements 92 by 1 through M-1 symbol periods (T) before being fed to respective first inputs of other multipliers 90.

A spreading code generation section 94 generates cyclic variations of common spreading code 38. FIG. 5 illustrates code generation section 94 in matrix form, which matrix takes on a cyclic Toeplitz form because the matrix elements hold cyclic variations of the same spreading code 38. As depicted in FIG. 5, different columns of the matrix supply code chips C_0 through C_{N-1} to second inputs of respective multipliers 90. Different rows of the matrix indicate different code chips to apply during different chip intervals. So long as the number (N) of chips in spreading code 38 is greater than or equal to the number (M) of symbols 36 per block 34, different code chips of the same code are applied to different symbols during any and all chip intervals.

Outputs of multipliers 90 provide respective spread substreams 74. FIG. 5 omits depiction of optional P/A reduction section 76 (FIG. 3) for convenience. Combining

section 78 takes the form of an adder, so that composite
signal 46 during each chip interval equals the sum of M
symbols 36, with each of the M symbols being premultiplied by
designated chips of common spreading code 38. Accordingly,
DSSS modulating section 44 temporally offsets application of
common spreading code 38 to unspread substreams 70 so that
the resulting spread substreams 74 correspond to unspread
substreams 70 modulated by cyclic variations of common
spreading code 38.

FIG. 6 shows a block diagram of the second embodiment of
DSSS modulation section 44. This second embodiment is
equivalent to the first embodiment of FIG. 5, but it is
implemented differently. Demultiplexer 68 (FIG. 3) is
omitted from FIG. 6 for convenience. In this embodiment,
spreading code generation section 94 need not be implemented
as a two-dimensional matrix having a different row to define
the different chips to be applied during different chip
intervals, as discussed above in connection with FIG. 5.
Rather, spreading code generation section 94 may be
implemented as a one-dimensional matrix having different
columns, and only one of those columns is simultaneously
applied to different unspread substreams 70. Spreading code
generation section 94 may be implemented as a shift register
configured to shift cyclically at the chip rate. In order to
achieve the appropriate temporal offsetting, delay elements
92 are now positioned between multipliers 90 and the adder of
combining section 78. Accordingly, in this second embodiment
of DSSS modulating section 44, DSSS modulating section 44
temporally offsets the application of common spreading code
38 to unspread substreams 70 so that the resulting spread
substreams 74 correspond to unspread substreams 70 modulated
by cyclic variations of common spreading code 38.

FIG. 7 shows a block diagram of the third embodiment of DSSS modulating section 44. This third embodiment is also equivalent to the first embodiment of FIG. 5, but is implemented differently. This third embodiment is a finite impulse response (FIR) implementation. In this third embodiment, symbol stream 42 (FIG. 3) is fed to a series of delay elements 96, each of which imparts a one chip interval delay. The series of delay elements 96 serves the role of demultiplexer 68 (FIG. 3) in this third embodiment, with the input to the first delay element 96 and the outputs of all delay elements 96 providing unspread substreams 70. Delay elements 92 (FIGs. 5-6) from the first and second embodiments of spreading section 72 are omitted.

Spreading code generation section 94 simply provides common spreading code 38, and need not be cycled because unspread substreams 70 to which spreading code 38 is applied are configured to perform the temporal offsetting requirements. Accordingly, symbol delay elements 92 are omitted and spreading code generating section 94 need not cycle the common spreading code or explicitly provide separate versions of spreading code 38 to separate unspread substreams 70. Nevertheless, in this third embodiment of DSSS modulation section 44, spreading section 72 temporally offsets application of common spreading code 38 by sequentially delaying symbols 36 to form unspread substreams 70 and applying spreading code 38 to the delayed symbols in unspread substreams 70 so that the resulting spread substreams 74 correspond to unspread substreams 70 modulated by cyclic variations of common spreading code 38.

FIG. 8 shows a first embodiment of CDM to TDM converter 82 included in receiver 24 (FIGs. 1 and 3). Desirably, CDM to TDM converter 82 is configured to complement DSSS

modulation section 44 of transmitter 22 (FIGs. 1 and 3). In particular, this first embodiment of CDM to TDM converter 82 is configured to complement any of the first through third embodiments of DSSS modulation section 44 discussed above in
5 connection with FIGs. 4-7.

CDM to TDM converter 82 includes a pulse shaping matched filter 98, the output of which feeds a mismatched filter 100. Pulse shaping matched filter 98 complements a pulse shaping filter (not shown) desirably implemented in transmission
10 section 48 of transmitter 22 (FIG. 3) to optimize signal-to-noise ratio and band-limit the signal. Pulse shaping matched filter 98 is desirably implemented using conventional techniques known to those skilled in the art.

Mismatched filter 100 accomplishes two functions. One
15 function is despreading and the other function is sidelobe suppression. In fact, mismatched filter 100 is desirably implemented to correspond to a spreader matched filter 102 upstream of a sidelobe suppression filter 104. One technique for implementing mismatched filter 100 is simply to implement
20 two filters coupled in series for the despreading and sidelobe suppression functions. In another technique (not shown) the two functions may be combined in a common filter.

Mismatched filter 100 experiences a signal-to-noise ratio typically worse than that of a matched filter. However, in
25 the preferred embodiments, mismatched filter 100 is desirably configured to achieve a relative efficiency of greater than 60%, and more preferably greater than 90%, compared to a matched filter.

Those skilled in the art will appreciate that the
30 configuration of common spreading code 38 is a strong determinant of the relative efficiency of mismatched filter 100. For example, conventional orthogonal pseudonoise (PN)

codes commonly used in conventional CDMA applications are
unacceptable because their mismatched filters achieve
relative efficiencies roughly around only 50%.

5   While a wide variety of different codes may be used with
the present invention, codes which have low aperiodic
autocorrelation sidelobes and a substantially flat spectral
analysis are preferred in this embodiment. Barker codes make
suitable codes because of aperiodic autocorrelation sidelobes
having magnitudes less than or equal to one. However, for
10   many applications the limited length (i.e., $N \leq 13$) and/or
prime numbered length of many Barker codes proves a
detriment. In such cases, other codes having a greater
length and slightly greater aperiodic autocorrelation
sidelobes, such as magnitudes less than or equal to two or
15   three are acceptable and may be easily derived by those
skilled in the art.

FIG. 9 shows an exemplary spectral analysis of a suitable
spreading code usable in connection with the present
invention. In particular, FIG. 9 represents an arbitrary
20   code for which a spectral analysis can be performed using a
time-frequency domain transformation, such as a Fourier
transform. While a code having a precisely flat spectral
analysis result is not a requirement, better results are
achieved when no frequency bin shows substantially more or
25   less signal level than other bins, as depicted in FIG. 9. As
an example, the signal level in each bin is desirably within
±25% of the average signal level taken over all bins. In
particular, for best results no bins should exhibit a nearly
zero signal level.

30   The implementation of mismatched filter 100 illustrated
in FIG. 8 will be readily understood by those skilled in the
art. Spreader matched filter 102 may be implemented using

the complex conjugate of spreading code 38 (FIG. 2) presented
in a reverse order. Sidelobe suppression filter 104 may be
implemented using well known FFT or linear programming
techniques.

5   The output of spreader matched filter 102 in mismatched
filter 100 is a composite signal 106 equivalent to the
autocorrelation function applied to each of the M unspread
and spread substreams 70 and 74 (FIG. 3 and 5-7) discussed
above.

10   FIG. 10 shows an exemplary timing diagram of the various
individual signal components present in composite signal 106
output from the matched filter 102 portion of mismatched
filter 100. For convenience, FIG. 10 depicts an exemplary
situation where the number of substreams 70 and 74 (i.e., M)
15 equals seven and the number (i.e., N) of chips in spreading
code 38 equals seven. Thus, each row in FIG. 10 represents
one of the seven substreams, and each row depicts
autocorrelation with an assumed rectangular pulse. Of
course, composite signal 106 is the sum of all rows in FIG.
20 10 rather than seven distinct signals.

       Assuming ideal synchronization where samples are taken at
the integral chip intervals of 0, 1, 2, ..., then in this
example, seven successive samples yield the signal levels of
the seven substreams. However, each sample in composite
25 signal 106 is corrupted by self-interference 108, caused by
sidelobes of the autocorrelation function. Accordingly,
sidelobe suppression filter 104 (FIG. 8) substantially
attenuates the self-interference 108 of the sidelobes while
not severely attenuating the autocorrelation peak.

30   Referring back to FIGs. 3 and 8, the output sidelobe
suppression filter 104 provides baseband signal 84, which
also serves as the output of CDM to TDM converter 82.

Baseband signal 84 is routed to TDM demodulation section 86.
Depending upon the severity of multipath remaining in
baseband signal 84 after processing through sidelobe
suppression filter 104, a rake receiver (not shown) or
5   equalizer (not shown) may be used in TDM demodulation section
86 to compensate for the multipath. While some inefficiency
may result from using a mismatched filter to despread
communication signal 26, any such inefficiency is more than
compensated for by a marked improvement in multipath
10   tolerance.

     While receiver 24 receives a communication signal 26 from
one transmitter 22, it may simultaneously receive other
communication signals 26 from other transmitters 22 in
adjacent radio coverage areas 28 (FIG. 1). Conventional CDMA
15   techniques may be used to prevent interference between such
diverse communication signals 26. For example, different
spreading codes 38 may be selected for use at different
transmitters 22. Such different spreading codes 38 are
desirably configured to have low cross-correlation sidelobes
20   among all spreading codes 38. If this option is selected,
only a few (e.g., 3-7) of such codes need be used to prevent
interference because interference should not be a problem
between communication signals 26 from non-adjacent radio
coverage areas 28 (FIG. 1). Alternatively, transmitter 22
25   and receiver 24 may include other stages to further
scramble/descramble spread spectrum signals using other
spreading codes.

     The embodiments of the present invention discussed above
and characterized by the timing depicted in FIG 4, wherein
30   composite signal 46 is influenced, at least for a portion of
the time, by symbols 36 from two different blocks 34, show
advantageous resilience in the presence of multipath.

However, alternate embodiments, discussed below, may provide even better performance in the presence of multipath for some applications.

FIG. 11 shows a timing diagram depicting how common spreading code 38 (FIG. 2) is applied to blocks 34 (FIG. 2) of unspread data substreams 70 (FIG. 3) in accordance with fourth and fifth embodiments of DSSS modulation section 44 (FIG. 3) in transmitter 22 (FIG. 3). Like FIG. 4 discussed above, FIG. 11 is presented in tabular form, with rows representing the application of the chips of common spreading code 38 to symbols 36 (FIG. 2). Columns in FIG. 11 depict successive blocks 34. As indicated by a shaded region in FIG. 11, spreading code 38 in the fourth and fifth embodiments is applied to unspread substreams 70 so that composite signal 46 is influenced, at all times, by symbols 36 from only common blocks 34.

FIG. 12 shows a block diagram of the fourth and fifth embodiments of DSSS modulation section 44. Demultiplexer 68 (FIG. 3) is omitted from FIG. 12 for convenience. In addition, in order to enable matrix multiplication operations discussed below, FIG. 12 represents that N symbols 36 (i.e. $a_{k,0}$ through $a_{k,N-1}$) are provided from demultiplexer 68 during each block 34 (FIG. 2). In other words, FIG. 12 represents that the number (M) of symbols 36 per block 34 equals the number (N) of chips in spreading code 38. Those skilled in the art will appreciate that when M < N, the number M of symbols 36 per block 34 may be made equal to N by padding with zeros so that the zeros are evenly distributed among the symbols 36. As an example, if M equals 4 and N equals 12, then 12 symbols 36 may be provided by following each symbol 36 in each block 34 with two zeros.

Unspread substreams 70, which provide N symbols 36 per block 34, pass to an optional time-frequency domain transformation section 110. Time-frequency domain transformation section 110 may be implemented as an inverse fast Fourier transform (IFFT). For purposes of the present discussion, the fourth embodiment of DSSS modulation section 44 shall be deemed to omit section 110, while the fifth embodiment shall be deemed to include section 110. Thus, unspread substreams 70 convey time domain data to spreading section 72 in the fourth embodiment and frequency domain data to spreading section 72 in the fifth embodiment.

While section 110 is not a requirement of the present invention, certain benefits may be achieved by the addition of section 110 as will be discussed below. Moreover, section 110, or the equivalent, is conventionally included in digital communication transmitters which implement an orthogonal frequency division multiplexed (OFDM) modulation format. In such situations, section 110 may be present for use in connection with the present invention at little additional complexity or expense.

Delay elements 92 (FIGs. 5-6) are omitted in the fourth and fifth embodiments of DSSS modulation section 44 to permit only symbols 36 concurrently present during a common block 34 to influence composite signal 46. However, spreading section 72 and spreading code generating section 94 are implemented in a manner similar to that discussed above in connection with the first and second embodiments of DSSS modulation section 44 (FIGs. 5-6). In particular, cyclic variations of a single common spreading code 38 are applied in the form of a cyclic Toeplitz matrix (see FIG. 5). While spreading code generating section 94 acts to multiply the 1 X N matrix of symbols 36 in each block 34 by spreading code 38 effectively

in the form of an N X N cyclic Toeplitz matrix, it may do so simply through a one-dimensional matrix having different columns applied to different unspread substreams 70 at different multipliers 90. Instead of selecting a spreading code 38 with low aperiodic autocorrelation sidelobes as discussed above in connection with the first, second and third embodiments of DSSS modulation section 44, the fourth and fifth embodiments of DSSS modulation section 44 are better served with a spreading code 38 having low periodic autocorrelation sidelobes and a substantially flat spectrum. Spreading code generation section 94 may be implemented as a shift register configured to shift cyclically at the chip rate. Spread substreams 74 output from multipliers 90 are combined in an adding circuit 78 to form a pre-composite signal 46', which is converted back into parallel streams at a demultiplexer (DEMUX) 112 into N chips per block 34, labeled $b_{k,0}$ through $b_{k,N-1}$ in FIG. 12.

Demultiplexer 112 provides one technique for forming a cyclic prefix 114. Chips $b_{k,0}$ through $b_{k,N-1}$ and cyclic prefix 114 are routed in parallel to inputs of a multiplexer (MUX) 116 for conversion into serial composite signal 46. In particular, chips $b_{k,0}$ through $b_{k,N-1}$ are associated with an intended order, in which chips $b_{k,0}$, $b_{k,1}$, $b_{k,2}$, ... $b_{k,p}$ occur first in pre-composite signal 46', and chips $b_{k,q}$, ... $b_{k,N-3}$, $b_{k,N-2}$, $b_{k,N-1}$ occur last in pre-composite signal 46'. FIG. 12 illustrates an example where the p = 2 first-occurring spread substreams in pre-composite signal 46' are repeated as cyclic prefix 114 so that they also occur last in composite signal 46. Of course, those skilled in the art will appreciate that the clock rate of multiplexer 116 is desirably sufficiently higher than the clock chip rate to accommodate cyclic prefix 114.

Transmission section 48 forms blocks 34 of communication signal 26 from blocks 34 of composite signal 46. Blocks 34 of communication signal 26 propagate to receiver 24 through a communication channel which may be unique to a specific

5 transmitter 22 location and receiver 24 location. Blocks 34 of communication signal 26 experience multipath and other types of distortion when propagating through this channel. The mathematical effect of this distortion is equivalent to multiplying composite signal 46 by the transfer function of

10 the channel which imposes the multipath.

As discussed above, each block 34 of composite signal 46 is formed from the matrix multiplication of the spreading code 38 with a block 34 of symbols 36. The effect of multipath distortion is then the matrix multiplication of the

15 matrix expression of the channel transfer function with this matrix product. Normally, a matrix multiplication does not observe a communicative mathematical property. In other words, the product of the channel transfer function by the spreading matrix does not necessarily equal the product of

20 the spreading matrix by the channel transfer function.

Due to the failure of the mathematical communicative property in matrix multiplication, normally equalization to compensate for multipath should be performed before despreading in receiver 22. Unfortunately, such equalization

25 is exceedingly difficult to successfully perform, due at least in part to requiring the implementation of a filter with characteristics equivalent to the inverse of the channel transfer function. The characteristics of the channel cannot be easily controlled, and channel transfer function quite

30 possibly has elements near zero. Attempting to form inverse filters of such characteristics often leads to unstable implementations.

However, the use of cyclic variations of common spreading code 38, when combined with cyclic prefix 114 and processed as discussed below in receiver 24, enables the mathematical communicative property. Consequently, despreading may now occur prior to equalization for multipath, thereby making effective equalization a relatively simple task.

FIG. 13 shows a second embodiment of CDM to TDM converter 82 for use with the fourth embodiment of the DSSS modulation section 44 (i.e., the time domain embodiment). The digitized IF form of communication signal 26, after being distorted through the communication channel, is applied to a demultiplexer (DEMUX) 118 and a synchronization (SYNC) section 120. An output of synchronization section 120 feeds a cyclic prefix removal section 122 of demultiplexer 118. Synchronization section 120 identifies the start of blocks 34, and cyclic prefix removal section 122 removes the first-occurring p chips from each block 34. As discussed above, the last-occurring p chips duplicate the first-occurring p chips, and the last-occurring p chips and all other chips remain in each block 34. The first-occurring p chips are removed because they are influenced by multipath from the previous block 34 of communication signal 26. All chips which remain in each block 34 are influenced only by multipath from that block 34.

The block 34 of chips, with cyclic prefix 114 (FIG. 12) removed, passes to mismatched filter 100 for despreading and equalization. As discussed above, due to the use of cyclic variations of spreading code 38 to spread symbols 36 and the inclusion of cyclic prefix 114, the matrix multiplication which characterizes the channel now observes the communicative mathematical property. Consequently, despreading may occur before equalization.

Despreading may take place using a despreading code generator 124, a despreading section 126, and a combining section 128. Despreading code generator 124, despreading section 126, and combining section 128 are identical in

5 structure to spreading code generator 94, spreading section 72, and combining section 78 in DSSS modulator section 44 of transmitter 22 (FIG. 12), with the despreading code generated in despreading code generator 124 being related to spreading code 38. In particular, despreading code chips D_n =

10 $IFFT(1/FFT(C_n))$, where IFFT and FFT denote inverse fast Fourier transform and fast Fourier transform, respectively, and C_n represents the chips of spreading code 38.

Spread substreams 130 are provided by demultiplexer 118 to multipliers 132 in despreading section 126 along with the

15 despreading code matrix from despreading code generator 124. The despreading code is applied in the form of a cyclic Toeplitz matrix due to the use of cyclic variations of a common spreading code to which the despreading code is related. Multipliers 132 provide despread substreams 134 to

20 combiner 128 to add despread substreams 134 on a chip by chip basis into a serial pre-composite baseband signal 136. Pre-composite baseband signal 136 is converted into parallel symbol substreams 140 at a demultiplexer (DEMUX) 138, and symbol substreams 140 are applied to a maximum likelihood

25 sequence estimation (MLSE) equalizer 142 or the equivalent. MLSE equalizer 142 may also be called a Viterbi equalizer. Parallel outputs from MLSE equalizer 142 feed a multiplexer (MUX) 144 which converts the parallel symbol substreams into baseband signal 84 for further processing by TDM demodulation

30 section 86 (FIG. 3).

Those skilled in the art will appreciate that an MLSE equalizer is a simple structure which is stable and can be

effectively configured to compensate for multipath. The
coupling of MLSE equalizer 142 downstream of despreading
section 126 is possible due to the use of cyclic variations
of common spreading code 38 in transmitter 22 and cyclic

5   prefix 114 to enable matrix multiplication exhibiting the
mathematical communicative property.

FIG. 14 shows a third embodiment of CDM to TDM converter
82 for use with the fifth embodiment of DSSS modulation
section 44 (i.e., the frequency domain embodiment), discussed

10   above in connection with FIG. 12. The digitized IF form of
communication signal 26, after being distorted through the
communication channel, is applied to demultiplexer (DEMUX)
118 and synchronization (SYNC) section 120, as discussed
above in connection with FIG. 13. Likewise, cyclic prefix

15   114 (FIG. 12) is removed at cyclic prefix removal section 122
of demultiplexer 118, as discussed above in connection with
FIG. 13.

Spread substreams 130 are provided by demultiplexer 118
to a time-frequency domain transformation section 146, which

20   complements time-frequency domain transformation section 110
(FIG. 12). Thus, if time-frequency domain transformation
section 110 in DSSS modulation section 44 implements an
inverse fast Fourier transform (IFFT), then time-frequency
domain transformation section 146 desirably implements a fast

25   Fourier transform (FFT).

Mismatched filter 100 couples downstream of time-
frequency domain transformation section 146. In this third
embodiment of CDM to TDM converter 82 mismatched filter 100
may be implemented in a manner that joins despreading and

30   equalization functions in a common frequency domain
equalizer. As illustrated in FIG. 14, coefficients for the
frequency domain equalizer take the form $D*_{H(n)}/D_{C(n)}$, where

$D_{c(n)}$ represents despreading code chips that are related to spreading code 38 in the manner discussed above in connection with FIG. 13 and $D^*_{H(n)}$ represents the complex conjugate of the transfer function of the channel. One reason why a

5 frequency domain equalizer is easy and effective to implement is that coefficients are not proportional to the inverse of the transfer function of the channel. While despreading code chips are related to the inverse of the FFT of the spreading code, such coefficients do not pose problems because the

10 designer controls the FFT of the code through code selection, and a spreading code having a substantially flat spectral response may be selected, as discussed above in connection with FIG. 9.

Parallel outputs of mismatched filter 100 pass in

15 parallel to hard decision sections 148, and parallel outputs of hard decision sections 148 are combined into serial baseband signal 84 in multiplexer (MUX) 144 for further processing in TDM demodulation section 86 (FIG. 3).

Due to the enabling of the mathematical communicative

20 property for matrix multiplication discussed above, mismatched filter 100 may reside downstream of time-frequency transformation section 146, which improves the efficacy and simplicity of the equalization and despreading functions.

In summary, the present invention provides an improved

25 method and apparatus for wireless communications. The present invention contemplates the combination of TDMA and spread spectrum techniques so that wireless communications capacity is increased over the capacities achievable through conventional TDMA and/or CDMA systems using an equivalent

30 amount of spectrum. Furthermore, robust, simple, and inexpensive processing techniques are usable in the present invention, making the present invention suitable for hubs,

subscriber units, mobile stations, fixed stations, portable
stations, and the like. The present invention may be adapted
to and used in conjunction with a variety of modulation and
multiple access techniques, such as frequency division
5   multiple access (FDMA) and orthogonal frequency division
multiplexing (OFDM). The advantages and improvements of the
present invention are achieved, at least in part through the
use of a composite RF communication signal which includes
signal components obtained by modulating diverse branches of
10   a single user's data stream using cyclic variants of a common
spreading code. The present invention is configured to
tolerate self-interference and is better able to tolerate
multipath than conventional DSSS-CDMA communication systems.

    Although the preferred embodiments of the invention have
15   been illustrated and described in detail, it will be readily
apparent to those skilled in the art that various
modifications may be made therein without departing from the
spirit of the invention or from the scope of the appended
claims. As one example, those skilled in the art will
20   appreciate that the order of time-frequency domain
transformation and spreading functions may be reversed from
that shown in Fig. 12.

CLAIMS

What is claimed is:

1. A method of operating a spread-spectrum-based wireless communication system to efficiently utilize spectrum in the presence of multipath, comprising:

dividing a stream of data-conveying symbols into a plurality of unspread substreams at a transmitter;

generating a common spreading code at said transmitter;

spreading, at said transmitter, each of said unspread substreams using said common spreading code to form a plurality of spread substreams;

combining, at said transmitter, said plurality of spread substreams to form a composite signal;

wirelessly transmitting, from said transmitter, a communication signal formed from said composite signal;

receiving said communication signal at a receiver; and

despreading said communication signal at said receiver using a mismatched filter to generate a baseband signal.

2. A method of operating a spread-spectrum-based communication system as claimed in claim 1 wherein said spreading activity comprises temporally offsetting application of said common spreading code to said plurality of unspread substreams so that said spread substreams correspond to said unspread substreams modulated by cyclic variations of said common code.

3. A method of operating a spread-spectrum-based communication system as claimed in claim 2 wherein:

said dividing activity produces successive blocks of symbols, where each block includes symbols concurrently present in each unspread substream, and each block has a block period; and

said temporally offsetting and combining activities are mutually configured so that for a portion of each block period said composite signal is responsive to symbols from two different blocks.

4. A method of operating a spread-spectrum-based communication system as claimed in claim 3 wherein said mismatched filter used in said despreading activity corresponds to a matched filter combined with a sidelobe suppression filter.

5. A method of operating a spread-spectrum-based communication system as claimed in claim 2 wherein:

said dividing activity produces successive blocks of symbols, where each block includes symbols concurrently present in each unspread substream; and

said temporally offsetting and combining activities are mutually configured so that said composite signal is responsive to symbols only from common blocks.

6. A method of operating a spread-spectrum-based communication system as claimed in claim 5 wherein:

said dividing and spreading activities produce M unspread substreams and M spread substreams, respectively, where M is an integer number;

said combining activity combines said M spread substreams so that, for each block, P of said M spread substreams occur

first in said composite signal, where P is an integer number less than M;

said combining activity additionally comprises, for each block, repeating said P spread substreams so that said P spread substreams also occur last in said composite signal; and

said method additionally comprises, between said receiving and despreading activities, removing said first-occurring P spread substreams from said communication signal.

7.   A method of operating a spread-spectrum-based communication system as claimed in claim 6 additionally comprising applying block encoding to an input stream of data so that encoding blocks coincide with said successive blocks of symbols.

8.   A method of operating a spread-spectrum-based communication system as claimed in claim 5 additionally comprising equalizing said communication signal at said receiver following said despreading activity using a maximum likelihood sequence estimation (MLSE) equalizer to compensate for multipath.

9.   A method of operating a spread-spectrum-based communication system as claimed in claim 2 additionally comprising:

performing a first time-frequency domain transformation on said unspread substreams at said transmitter prior to said spreading activity; and

performing a second time-frequency domain transformation on said communication signal at said receiver prior to said despreading activity.

10. A method of operating a spread-spectrum-based communication system as claimed in claim 9 additionally comprising equalizing said communication signal at said receiver following said second time-frequency domain transformation using a frequency domain equalizer to compensate for multipath.

11. A method of operating a spread-spectrum-based communication system as claimed in claim 2 wherein said cyclic variations of said common code are applied to said unspread substreams as a matrix in a cyclic Toeplitz form.

12. A method of operating a spread-spectrum-based communication system as claimed in claim 1 wherein said common code is generated so that said mismatched filter exhibits a relative efficiency greater than 60% compared to a matched filter.

13. A method of operating a spread-spectrum-based communication system as claimed in claim 1 wherein said common code is generated so that a spectral analysis of said common code exhibits a substantially flat response.

14. A method of operating a spread-spectrum-based communication system as claimed in claim 1 wherein said receiver is a first receiver, said mismatched filter is a first mismatched filter, said baseband signal is a first baseband signal, and said method additionally comprises:
    receiving said communication signal at a second receiver;

despreading said communication signal in said second receiver using a second mismatched filter to generate a second baseband signal;

generating said stream of data-conveying symbols as a time division multiple access (TDMA) stream having a plurality of time slots wherein a first one of said plurality of time slots is assigned to said first receiver and a second one of said plurality of time slots is assigned to said second receiver;

evaluating said first baseband signal at said first receiver to detect said first one of said time slots; and

evaluating said second baseband signal at said second receiver to detect said second one of said time slots.

15.   A method of operating a spread-spectrum-based communication system as claimed in claim 14 wherein:

said transmitter is a first transmitter and said communication signal is a first communication signal, said first transmitter being configured so that said first communication signal substantially occupies a predetermined spectrum and said first communication signal is detectable throughout a first radio coverage area; and

said method additionally comprises transmitting a second communication signal from a second transmitter, said second communication signal substantially occupying said predetermined spectrum and being detectable throughout a second radio coverage area which is adjacent to said first radio coverage area.

16. A spread-spectrum-based communication system which efficiently utilizes spectrum in the presence of multipath, said communication system comprising:

a demultiplexer for dividing a stream of data-conveying symbols into a plurality of unspread substreams;

a spreading section coupled to said demultiplexer and configured to generate spread substreams from said plurality of unspread substreams, said spreading section being configured so that said spread substreams correspond to respective ones of said unspread substreams modulated by cyclic variations of a common spreading code;

a combining section coupled to said spreading section and configured to form a composite signal in response to said spread substreams;

a transmission section coupled to said combining section and configured to wirelessly transmit a communication signal formed from said composite signal;

a receiving section configured to receive said communication signal; and

a despreading section coupled to said receiving section, said despreading section being configured to generate a baseband signal in response to said communication signal.

17. A spread-spectrum-based communication system as claimed in claim 16 wherein said despreading section comprises a mismatched filter.

18. A spread-spectrum-based communication system as claimed in claim 17 wherein said spreading section and said mismatched filter of said despreading section are mutually configured so that said mismatched filter exhibits a relative efficiency greater than 60% compared to a matched filter.

19. A spread-spectrum-based communication system as claimed in claim 17 wherein:

said demultiplexer produces successive blocks of symbols, where each block includes symbols concurrently present in each unspread substream, and each block has a block period;

said spreading section is configured so that for a portion of each block period said composite signal is responsive to symbols from two different blocks; and

said mismatched filter corresponds to a matched filter combined with a sidelobe suppression filter.

20. A spread-spectrum-based communication system as claimed in claim 16 wherein said spreading section is configured so that a spectral analysis of said common code exhibits a substantially flat response.

21. A spread-spectrum-based communication system as claimed in claim 16 additionally comprising a time division multiple access (TDMA) modulation section coupled to said demultiplexer, said TDMA modulation section being configured so that said communication signal is a TDMA signal for which recipients are distinguished from one another by being assigned to different time slots.

22. A spread-spectrum-based communication system as claimed in claim 21 wherein:

said transmission section is a first transmission section, and said communication signal is a first communication signal;

said communication system has first and second adjacent radio coverage areas with said first communication signal

being transmitted to said first adjacent radio coverage area;
and

said communication system additionally comprises a second
transmission section configured to transmit a second
communication signal to said second adjacent radio coverage
area, said first and second communication signals being
transmitted using a common spectrum.

23. A spread-spectrum-based communication system as
claimed in claim 16 wherein:

said demultiplexer produces successive blocks of M
symbols that concurrently influence said unspread substreams,
where M is an integer number;

said spreading section is configured to produce M spread
substreams, said M spread substreams being responsive to
symbols only from common blocks;

said combining section is configured so that, for each
block, P of said M spread substreams occur first in said
composite signal, where P is an integer number less than M;

said combining section is further configured so that, for
each block, said P spread substreams are repeated so that
said P spread substreams also occur last in said composite
signal; and

said communication system additionally comprises a cyclic
prefix removal section coupled between said receiving and
despreading sections for removing said first-occurring P
spread substreams from said communication signal.

24. A spread-spectrum-based communication system as
claimed in claim 16 additionally comprising a maximum
likelihood sequence estimation (MLSE) equalizer coupled

downstream of said despreading section to compensate for multipath.

25. A spread-spectrum-based communication system as claimed in claim 16 wherein:

said communication system additionally comprises a first time-frequency domain transformation section coupled between said demultiplexer and said spreading section;

said communication system additionally comprises a second time-frequency domain transformation section coupled between said receiver and said despreading section; and

said despreading section comprises a frequency domain equalizer to compensate for multipath.

26. A time division multiple access (TDMA), spread-spectrum-based communication system which efficiently utilizes spectrum in the presence of multipath, said communication system comprising:

a plurality of transmitters configured to wirelessly transmit TDMA communication signals which convey messages in adjacent radio coverage areas in accordance with a frequency reuse pattern substantially equal to one;

a plurality of receivers located in said adjacent radio coverage areas wherein each receiver is configured to detect ones of said messages intended for said each receiver by identifying time slots assigned to said each receiver;

wherein each of said transmitters comprises:

a demultiplexer for dividing a TDMA stream of data-conveying symbols into a plurality of unspread substreams;

a spreading section coupled to said demultiplexer and configured to generate spread substreams from said plurality of unspread substreams, said spreading section being configured so that said spread substreams correspond to respective ones of said unspread substreams modulated by cyclic variations of a common spreading code;

a combining section coupled to said spreading section and configured to form a composite signal in response to said spread substreams;

a transmission section coupled to said combining section and configured to transmit one of said TDMA communication signals formed from said composite signal; and

wherein each of said receivers comprises:

a receiving section configured to receive one of said TDMA communication signals; and

a despreading section coupled to said receiving section, said despreading section being configured to generate a baseband signal in response to said TDMA communication signal.

METHOD AND APPARATUS FOR WIRELESS COMMUNICATIONS

ABSTRACT OF THE DISCLOSURE

A communication system (20) uses TDMA techniques to
5   distinguish intended recipients of a communication signal
(26) from one another, and direct sequence spread spectrum
(DSSS) techniques to encode and distinguish diverse parallel
substreams (70, 74) of each user's data stream. Parallel
unspread substreams (70) are spread using cyclic variations
10   of a common spreading code (38). In one embodiment, the
common spreading code (38) is chosen for low aperiodic
autocorrelation sidelobes and a substantially flat spectral
analysis. In another embodiment the common spreading code
(38) is chosen for low periodic autocorrelation sidelobes and
15   a substantially flat spectral analysis. In one embodiment,
the use of cyclic variations of the spreading code (38) along
with a cyclic prefix (114) enables the mathematical
communicative matrix multiplication property, thereby
permitting equalization for multipath to occur following or
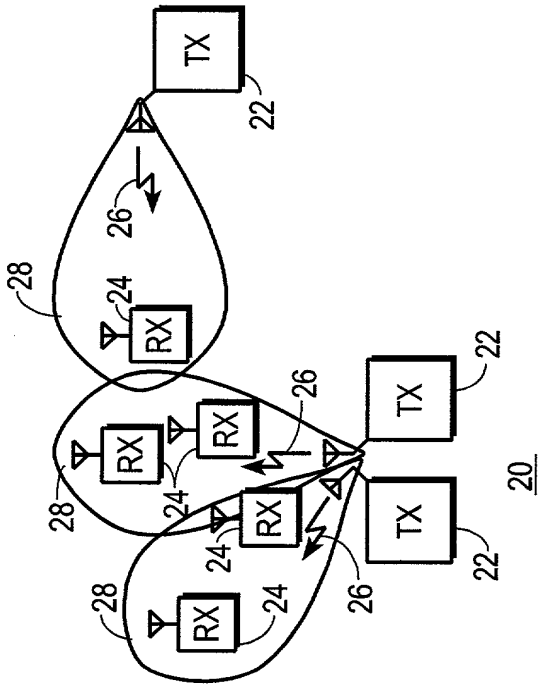20   in conjunction with despreading.

FIG. 2

FIG. 1

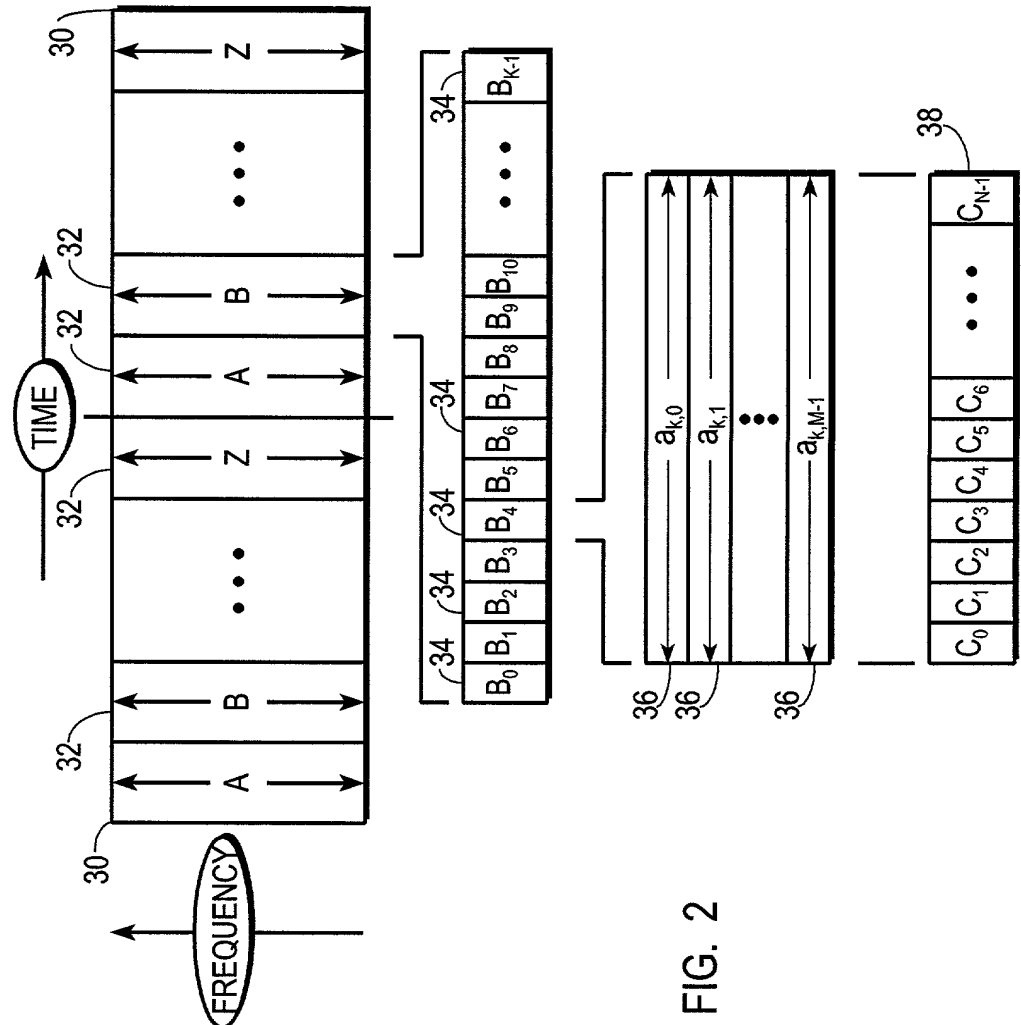2272-010

FIG. 4

k = -1	k = 0	k = +1

FIG. 5

FIG. 6

FIG. 7

$a_{k,m}$ — 36

DELAY T_c

DELAY T_c

DELAY T_c

96 96 96

ADD 78

46

70 90 70 74 74 74

90 90 90

74 × 74 × 74 ×

70 70 70

44

C_0 C_1 ... C_{N-2} C_{N-1}

94

FIG. 9

AMPLITUDE

FREQUENCY

FIG. 8

PULSE SHAPING MATCHED FILTER

98

26

100

SPREADER MATCHED FILTER

102

SIDELOBE SUPPRESSION FILTER

104

84

106

MISMATCHED FILTER

82

FIG. 10

FIG. 11

FIG. 12

82

FIG. 13

FIG. 14

Declaration and Power of Attorney For Patent Application

As a below-named inventor, I hereby declare that:
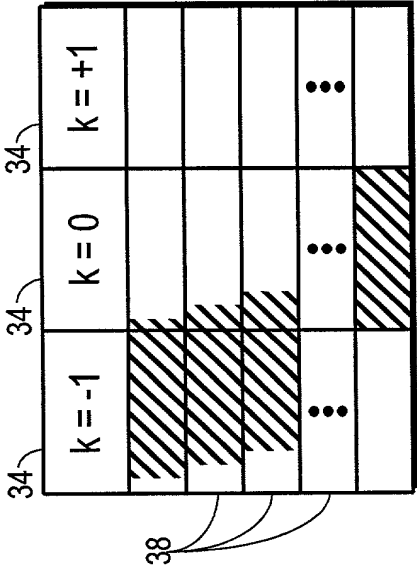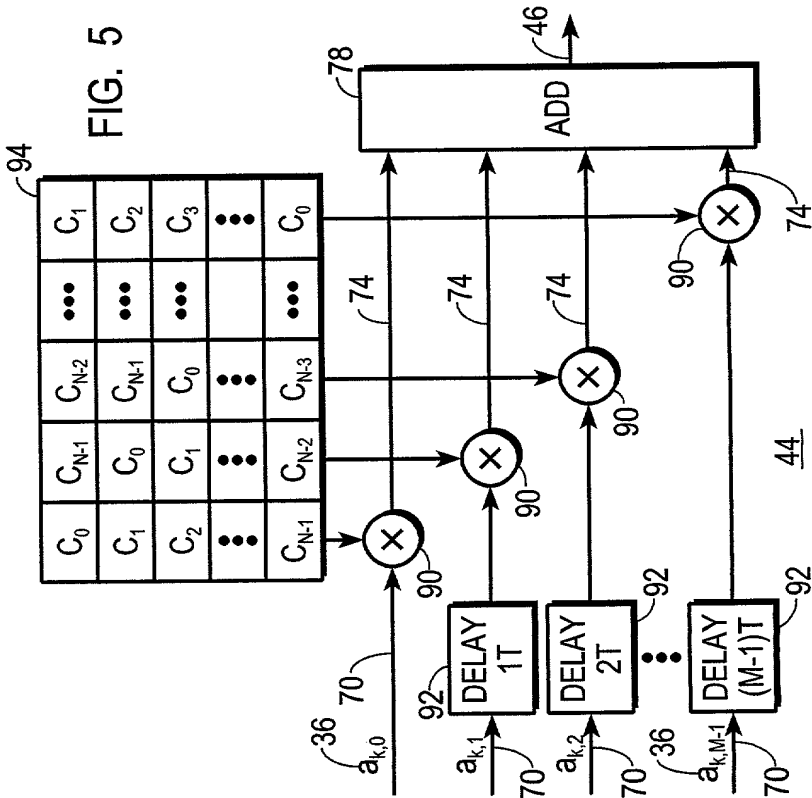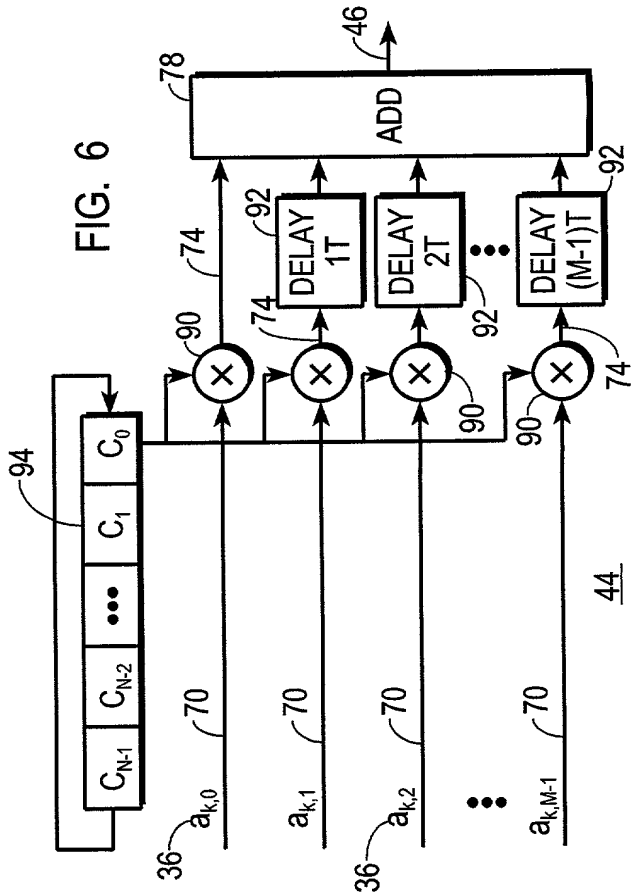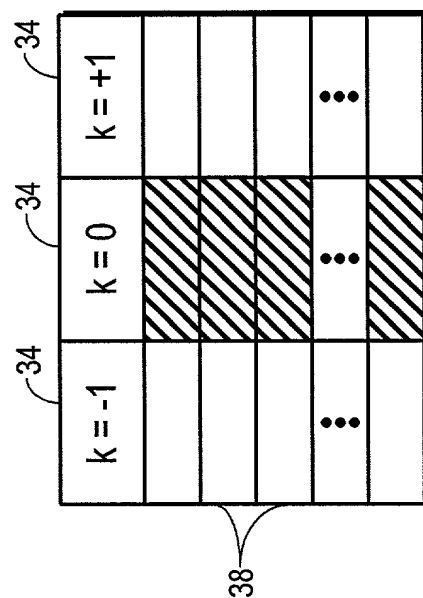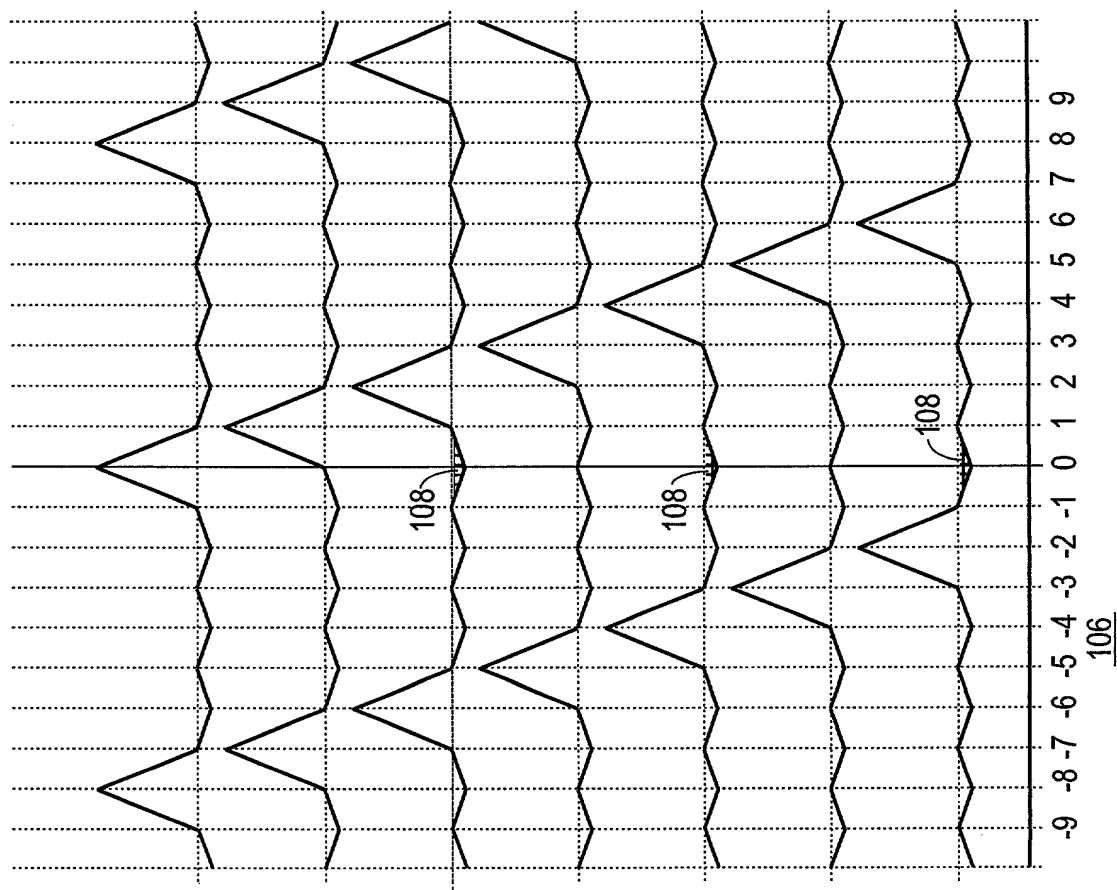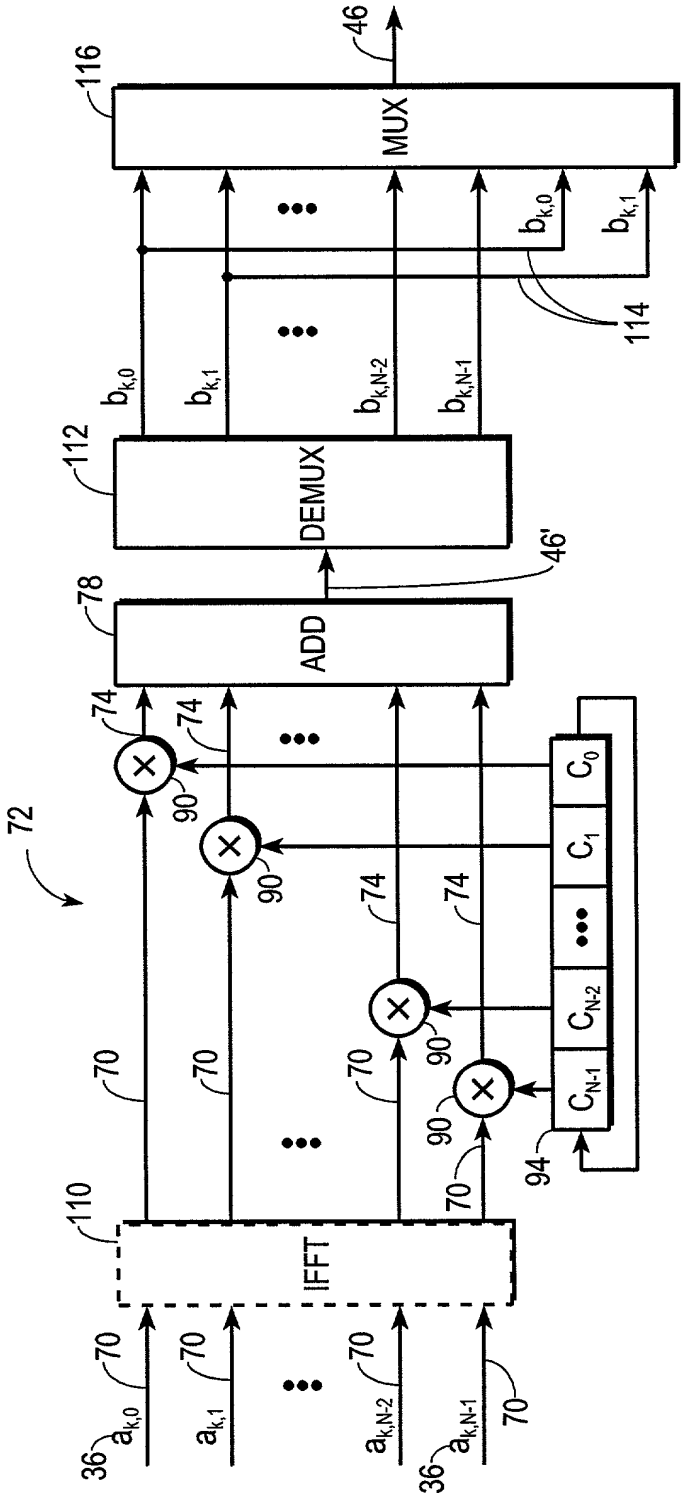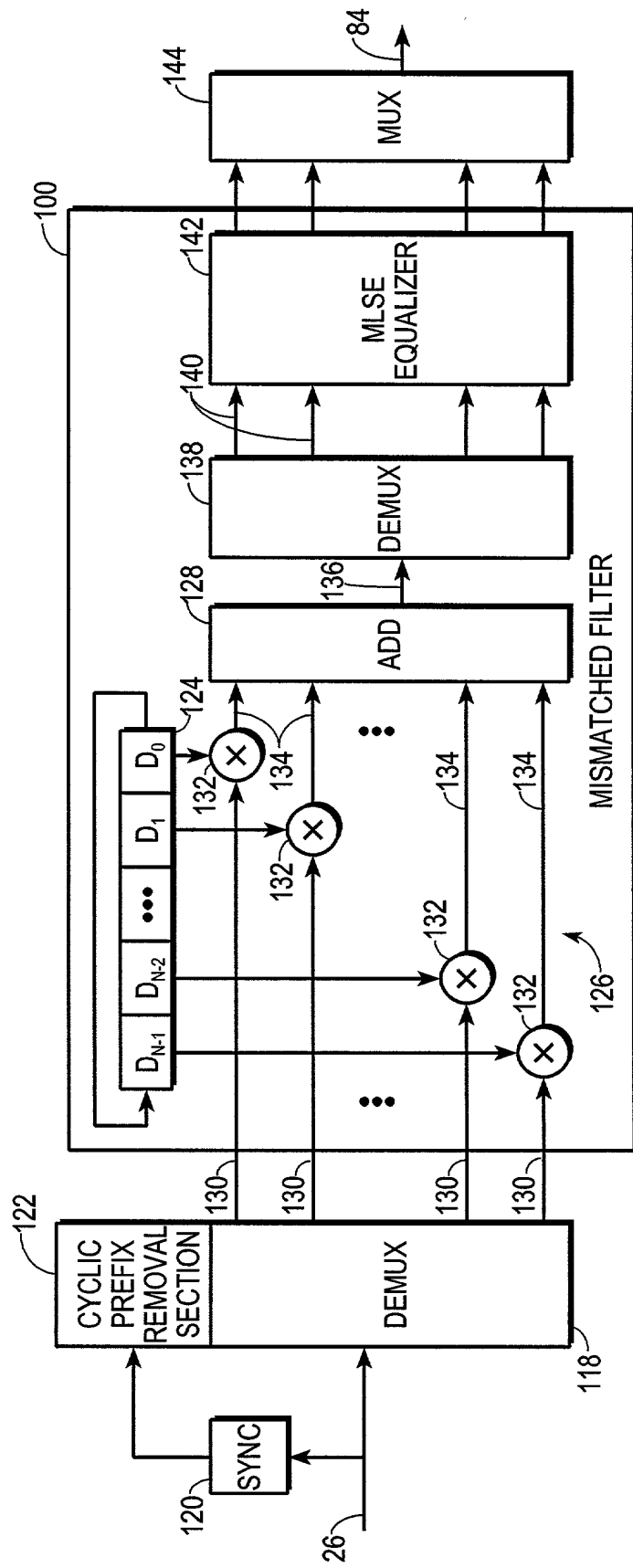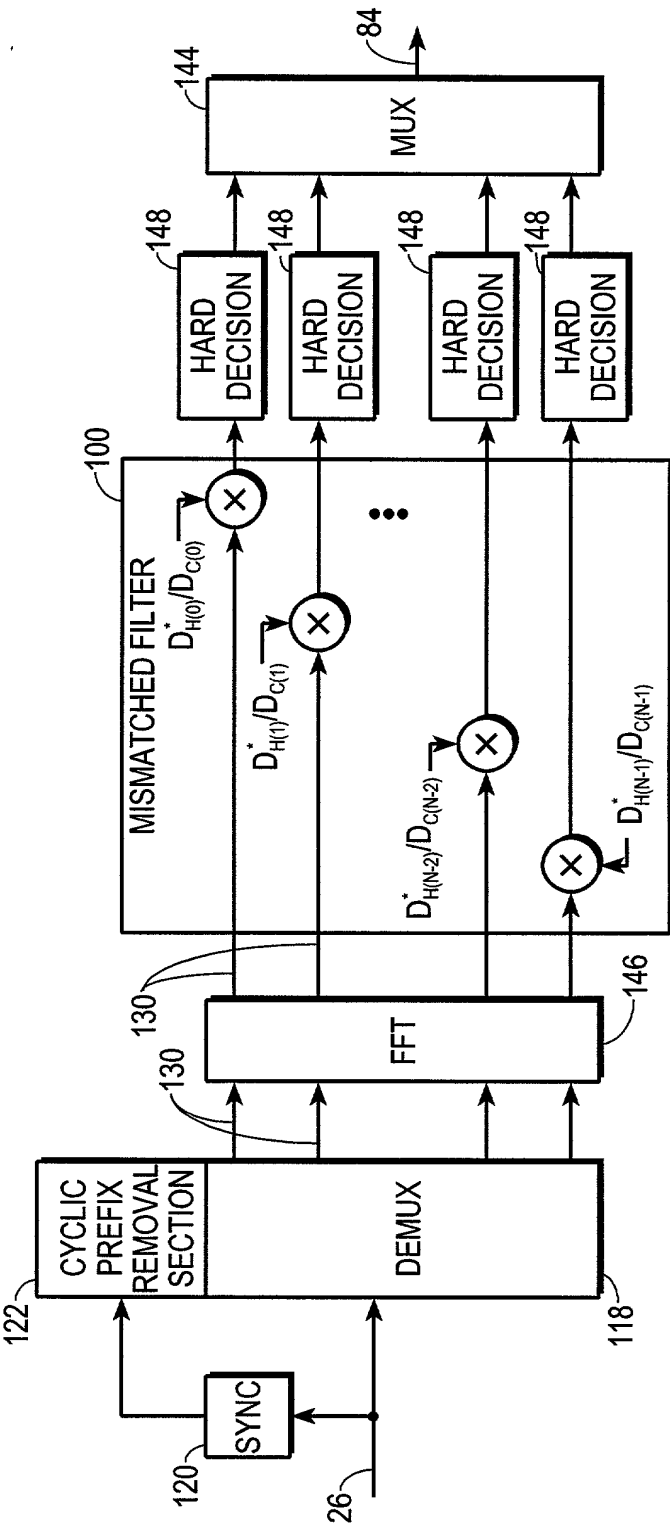
My residence, post office address and citizenship are as stated below next to my name,

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled *METHOD AND APPARATUS FOR WIRELESS COMMUNICATION*, the specification of which

(check one)

___X___ is attached hereto.

_____ was filed on _____ as

Application Serial No. _____

and was amended on _____
               (if applicable)

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, §1.56(a).

I hereby claim foreign priority benefits under Title 35, United States Code, §119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Prior Foreign Application(s)   **Priority Claimed**

			Yes	No
(Number)	(Country)	(Day/Mo./Yr. Filed)		
			Yes	No
(Number)	(Country)	(Day/Mo./Yr. Filed)		
			Yes	No
(Number)	(Country)	(Day/Mo./Yr. Filed)		

I hereby claim the benefit under Title 35, United States Code, §120 of any United States applications(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States Application in the manner provided by the first paragraph of Title 35, United States Code, §112, I

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acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, §1.56(a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

(Applic. S/N)	(Filing Date)	(Status--pend., pat., abandoned)

(Applic. S/N)	(Filing Date)	(Status--pend., pat., abandoned)

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith. (list name and registration number)

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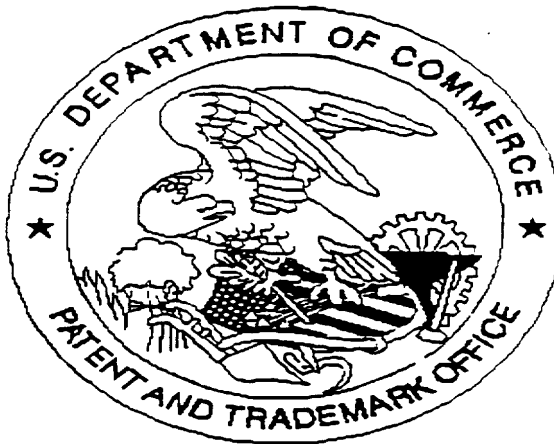
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